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Glenn Research Center

Uncertainty Analysis Considerations for Wind Tunnel Managers

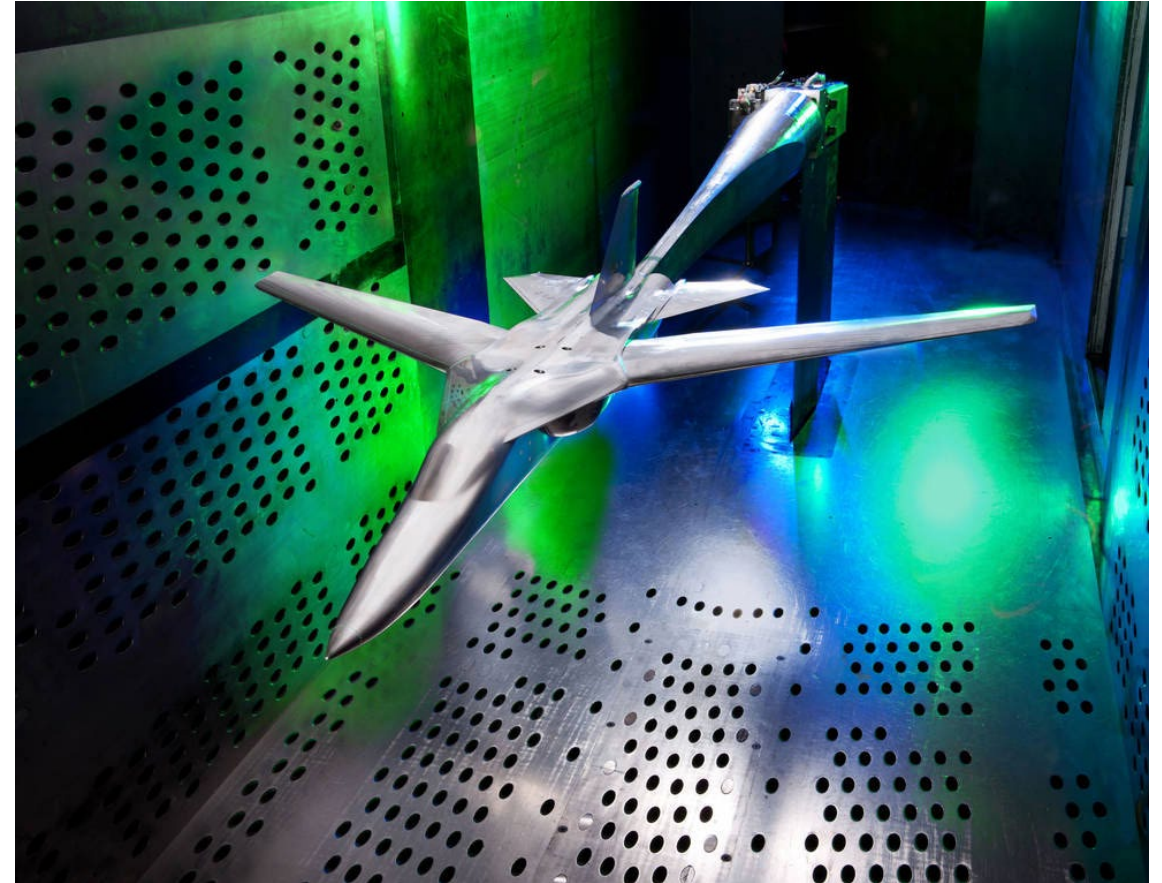
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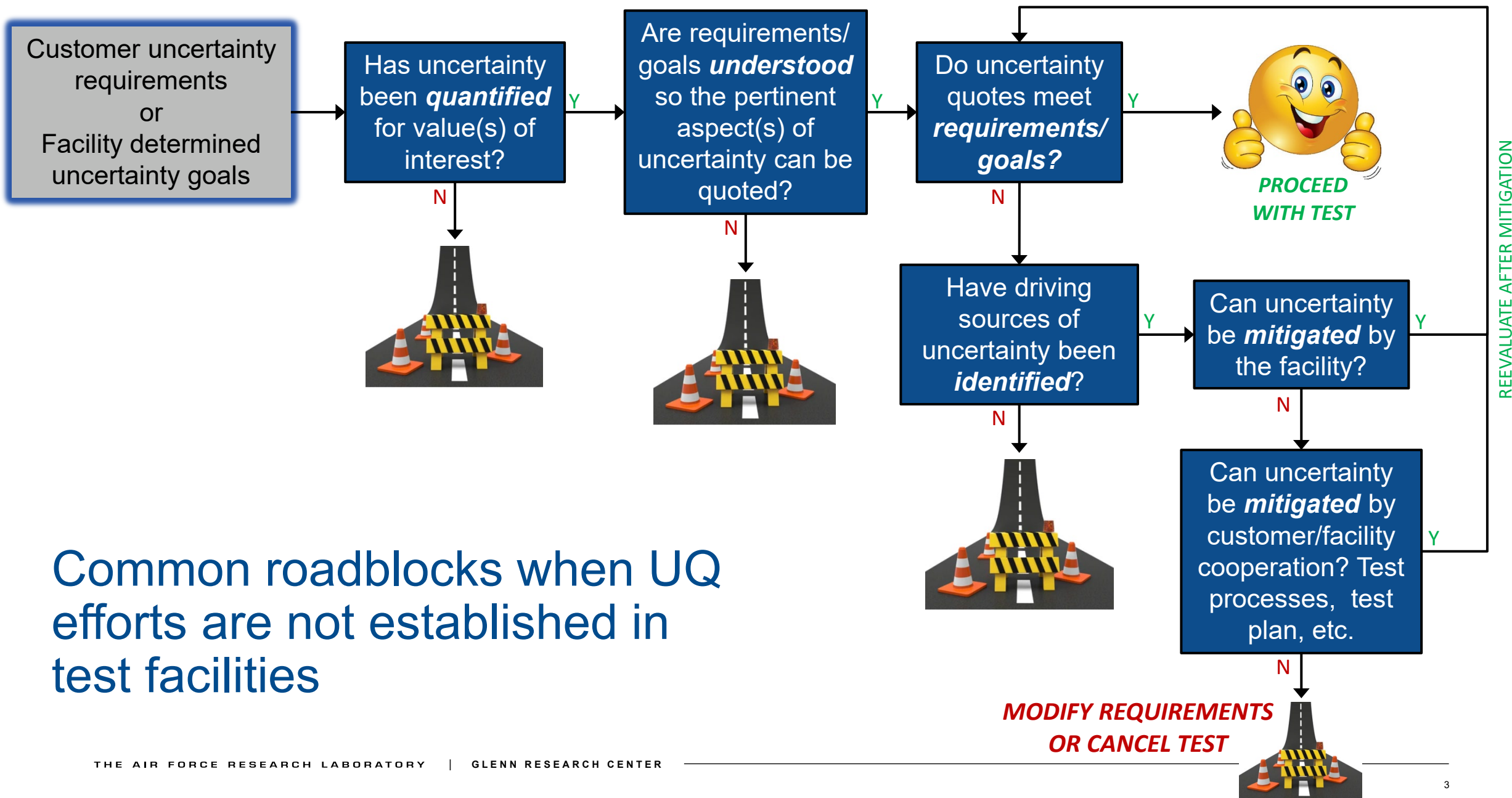
STAI, BUFFALO NY, May 22nd-25th, 2022

Do we need to quantify uncertainty?

- Qualitative evaluation used to suffice
- Now, customers ask about uncertainty and want quantitative answers
 - Some customers need it to evaluate adequacy of facility to meet test objectives
 - Most want it to “check the box”
- Regardless of why customers want it, uncertainty quantification (UQ) is becoming more necessary as gut feeling and engineering judgment may be insufficient
 - When is engineering judgement sufficient?
 - Pass/fail objectives
 - Large deltas
 - Low sensitivities
 - When isn't it sufficient?
 - Small margins
 - High risk objectives



<https://www.nasa.gov/sites/default/files/thumbnails/image/process-improvement-gallery2.jpg>



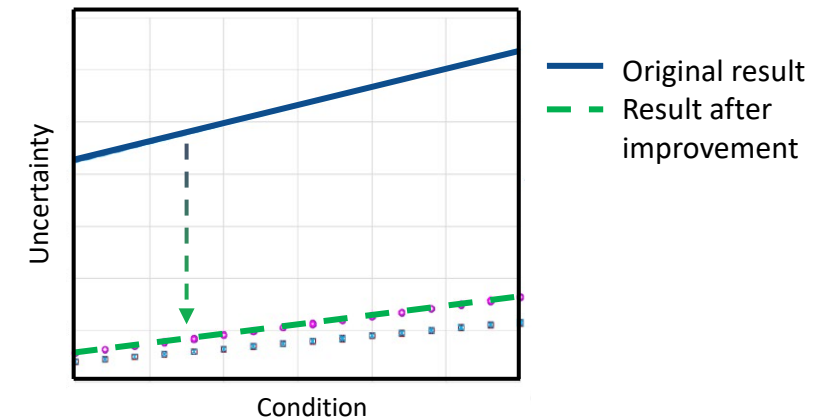
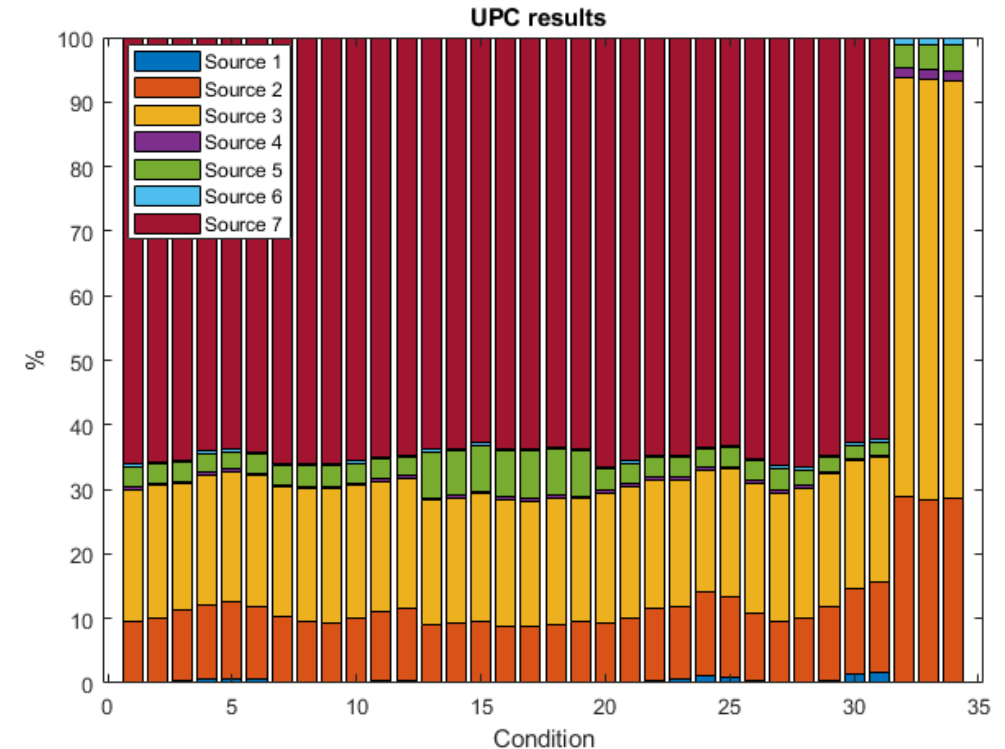


Is there a disconnect between test objectives and UQ?

- Common sequence of events:
 - Customer gives test objective
 - Customer/tester defines test methodology
 - Tester asks, “What uncertainty/accuracy do you need?”
 - Customer gives value (or more often: “What’s the best you can do?”)
 - Tester attempts to select sensors to achieve required uncertainty/accuracy for identified methodology
 - If uncertainty/accuracy requirement not met (if it exists):
 - Buy new sensor that meets requirement
 - If it doesn’t, tell the customer what the best you can do is (magically, this is usually deemed “ok”)
- Uncertainty as part of trade-space:
 - Customer gives test objective
 - Customer gives uncertainty requirement
 - Requires full understanding of *why* the objective is the objective, what decisions will be made from the data/analysis, and sensitivities
 - Tester/customer determine test methodology/sensors to achieve requirement with UQ as part of trade space
 - Excessively low uncertainty usually requires cost and time to achieve

Examples of UQ results

- Results for each facility are unique
 - Even similar facilities can differ in many ways
 - Installation procedures
 - Methods of condition control
 - Execution of test matrices (DOE, etc.)
 - Instrumentation
 - Monitoring and calculation of facility conditions
 - Calculation of critical variables
 - Etc...
- Difficult to predict which uncertainty sources are most influential/consequential without thorough analysis
- When better accuracy is required, it is often assumed that changing to better (= more expensive) instrumentation will provide better results
 - Occasionally, this has proven true in GRC's analyses
 - Most often, other sources are more influential



Challenges, benefits, drawbacks to UQ

- Challenges

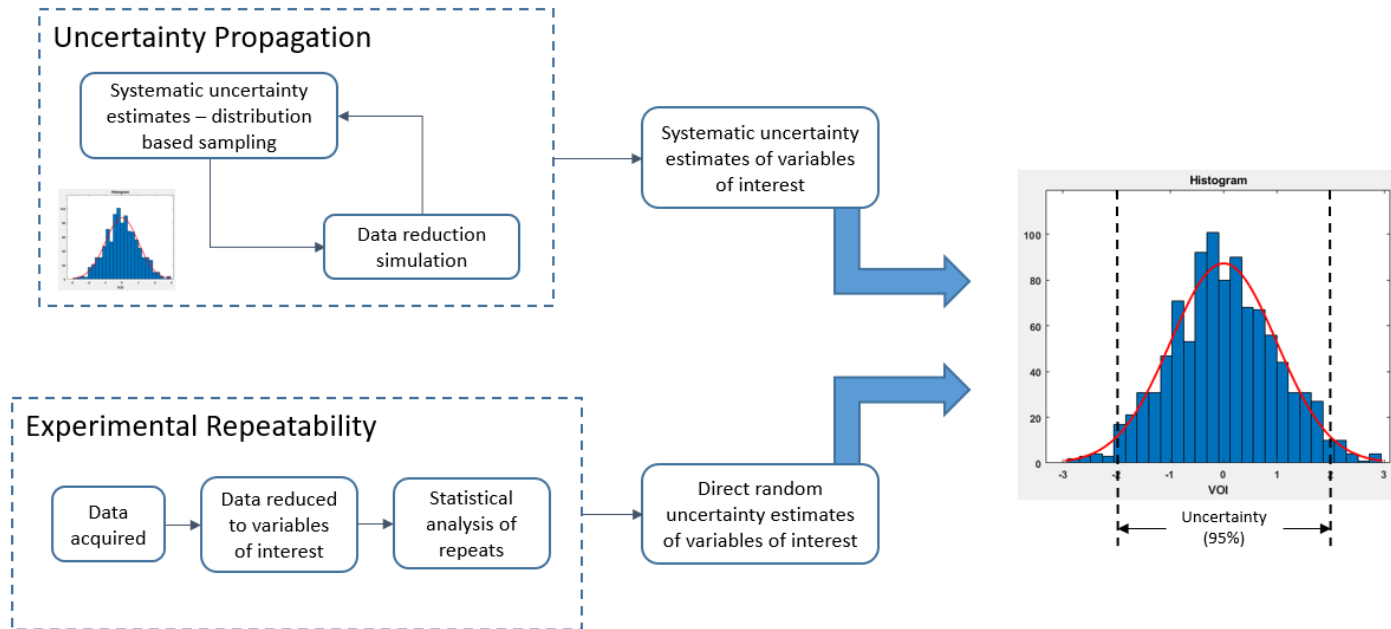
- Time required for extensive analysis
- Acquiring or gathering data
 - Accessibility of secure data
 - Time/Cost to run check standards, etc.
- Explanation required (to facilities, customers)
 - Not “just a number”

- Benefits

- Identify highest uncertainty sources
 - Determine effective investment strategies to improve data quality
- Better estimates of data quality
- Facility baseline data audit

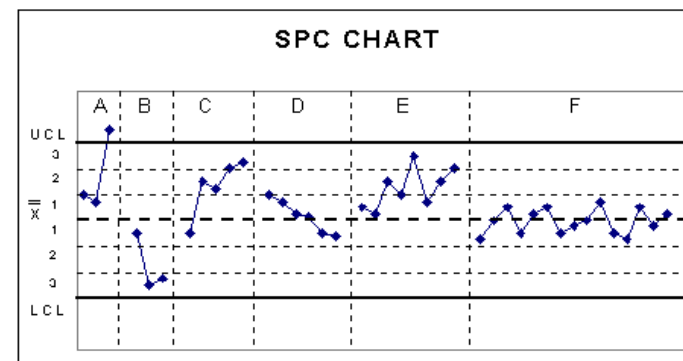
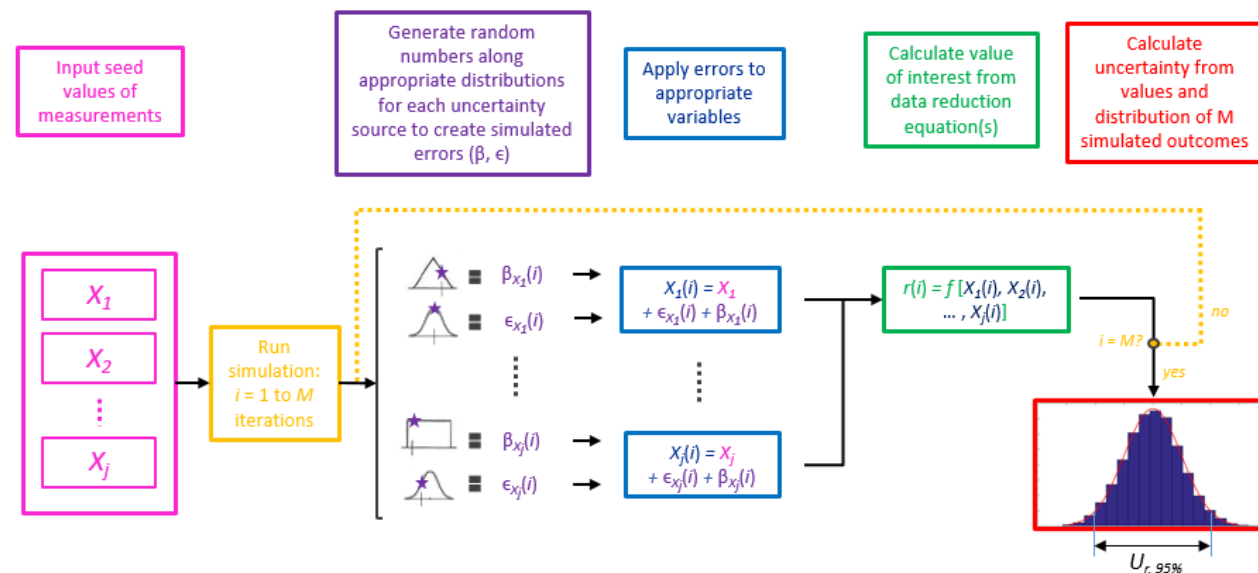
- Drawbacks

- Managing expectations
- Difficult to keep results up to date



How can managers “invest” in uncertainty?

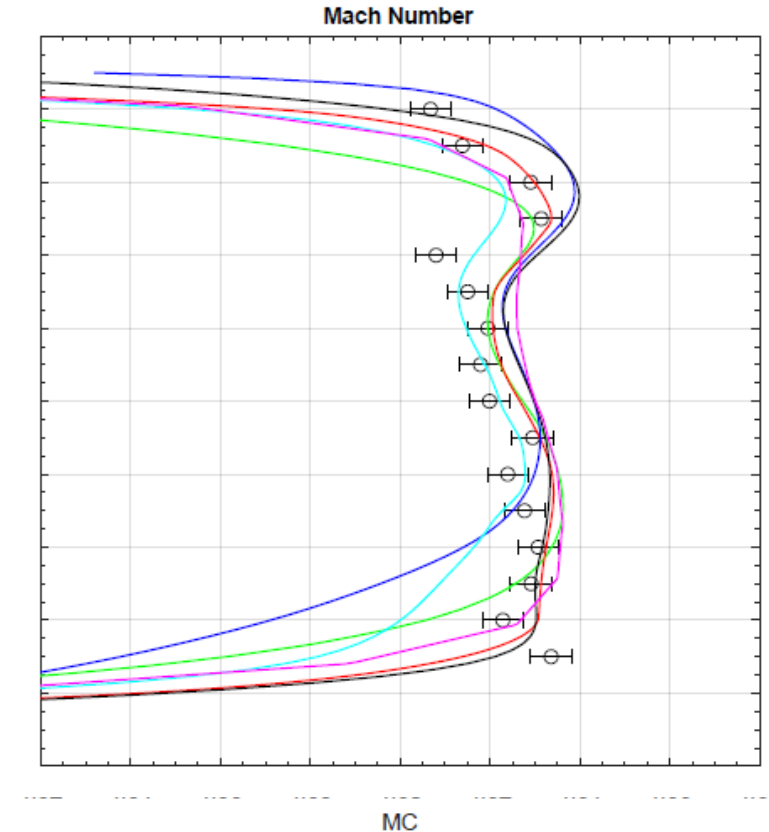
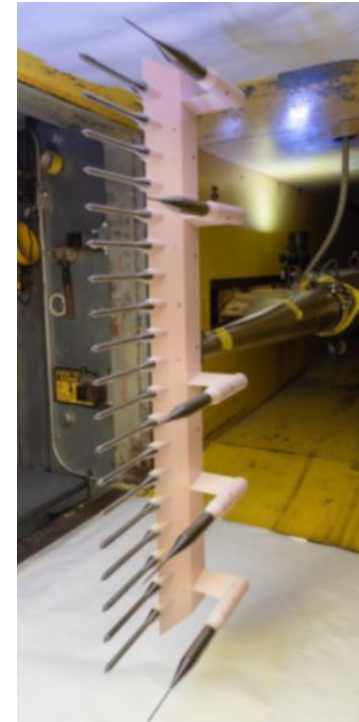
- Expectations
 - Part-time vs. full-time effort by individuals
 - Not a trivial undertaking
 - Tends to be put on the “back burner” if not a dedicated effort
 - Requires training and understanding to implement well
- Things that should be considered
 - Danger of overpromising
 - How to quantify value/success
 - Pros/Cons of publishing results
- Establishing expertise in work force
- Establishing check standard programs
 - Facility health
 - Data quality assurance



<https://www.moresteam.com/toolbox/statistical-process-control-spc.cfm>

Lessons learned in current UQ efforts

- Dedicated team vs. facility-by-facility approach
- Long lead time from start to finish, especially for new practitioners
- Facility engineers MUST be on board to provide necessary information to uncertainty teams/individuals
 - Data reduction details
 - Instrumentation details
 - Calibration and characterization procedures
- Uncertainty teams given opportunity to lean on facility experts
 - Improvement scenarios and simulations
- Include uncertainty team in customer discussions early in test planning
 - This rarely happens but could alleviate problems later if it became standard practice



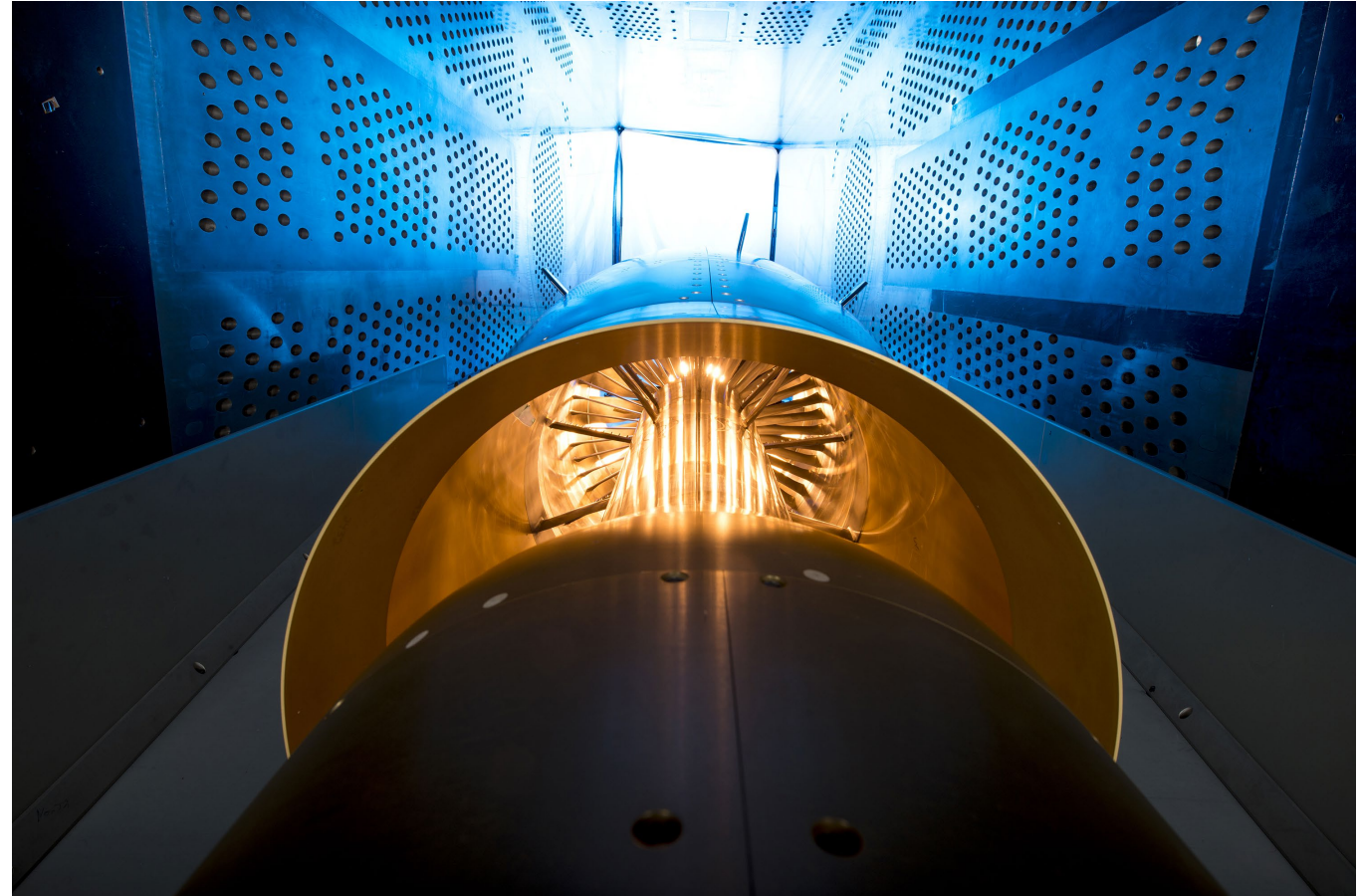


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What is the customer and manager perspective on facility UQ?

- What is desired from customers regarding UQ?
 - Report pre-test?
 - Post-test, test-specific evaluation?
 - Ballpark figures?
 - “Check the box”?
- Do facility managers and engineers see value in the UQ efforts that are in progress?
 - What could be improved or increase value?
- Other discussion questions...



https://www.nasa.gov/sites/default/files/thumbnails/image/bli_grc.jpg



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Questions?